National Highway Traffic Safety Administration

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Update on NHTSA Roof Ejection Research

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FMVSS No. 226 – Ejection Mitigation

- **Original Purpose:** Requirements for **ejection mitigation systems** to reduce the likelihood of complete and partial ejections of vehicle occupants through **side windows** during rollovers or side impacts.
- Received comments on NPRM regarding roof and backlight ejections
- Final Rule (Jan 2011) preamble says, **"NHTSA is interested in learning more about roof ejections** and would like to explore this area further… The results of this work may find that future rulemaking on roof ejections could be warranted."
  - Mitigating backlight ejection determined to not be cost effective
  - Mitigating roof ejection determined to be potentially cost effective, but the agency was not in a position to extend coverage to roof glazing in the final rule due to the lack of a proven performance test procedure for roof glazing.

Crash Data: Annualized Estimates

All Passenger Vehicle Occupants
Ejected Through Closed Roof Glazing (Sunroof, Moonroof, T-top)
All Crash Types
Annualized 2002-2012 NASS-CDS with Fatalities Adjusted to 2002-2012 FARS

Ejection Type	Belt Use	MAIS 1-2	MAIS 3-5	Fatality
Complete	No	183	92	156
Complete	Yes	0	0	11*
Partial	No	2	60	55
Partial	Yes	151	47	10
Total		336	200	233

* Unlikely to benefit from countermeasures

Initial Roof Ejection Mitigation Evaluation

- Purpose: To conduct an initial assessment of the feasibility of reducing occupant ejections through roof glazing by the use of laminated glass and to assess options for full-vehicle testing.
  - Guided impactor (40 lb) directed toward roof glazing (pre-broken) from inside the vehicle.
    - FMVSS No. 226 test speeds (10 and 12.5 mph)
  - Guided impactor (40 lb) directed toward roof glazing (pre-broken) from outside the vehicle.
    - FMVSS No. 226 test speeds (10 and 12.5 mph)
  - Free-Motion Headform (FMH) (10 lb) directed toward roof glazing (pre-broken) from inside the vehicle.
    - Higher test speeds to maintain energy equivalency with guided impactor tests

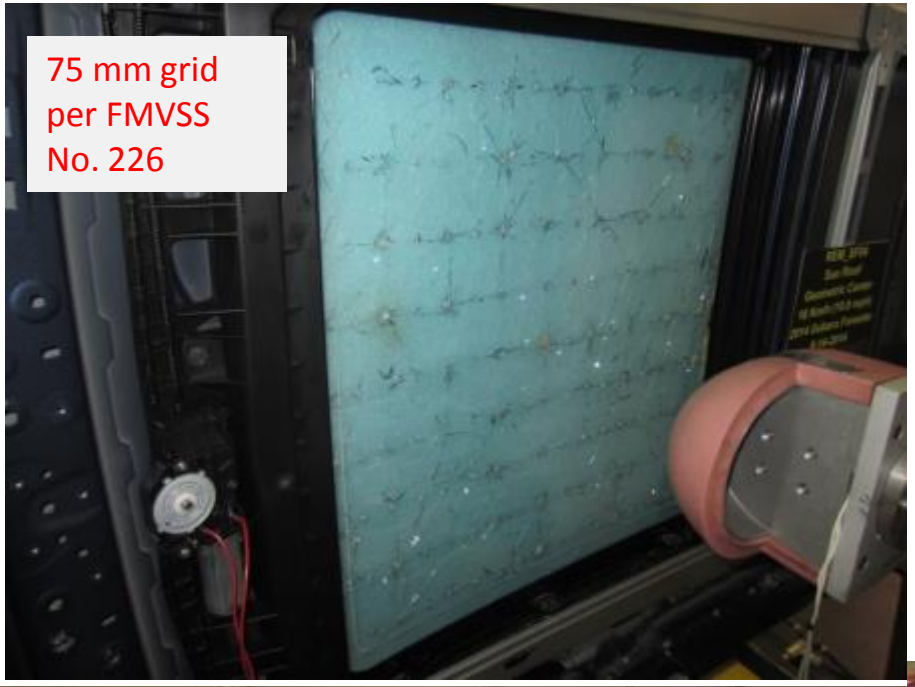
Impactors

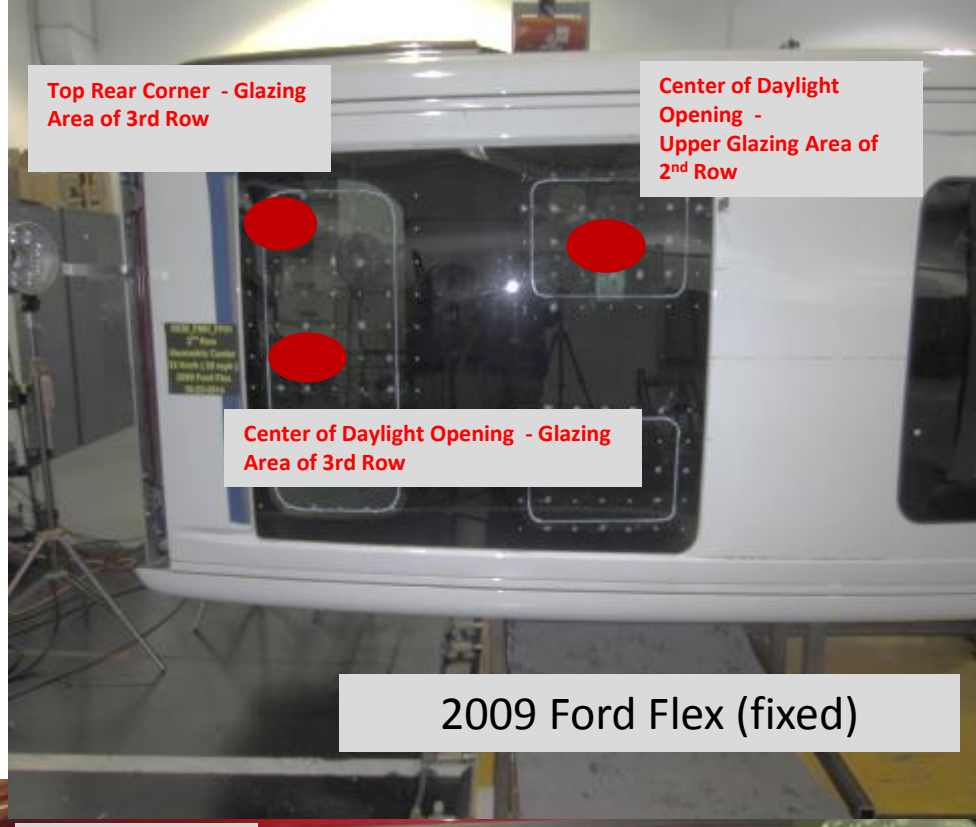
Guided Impactor

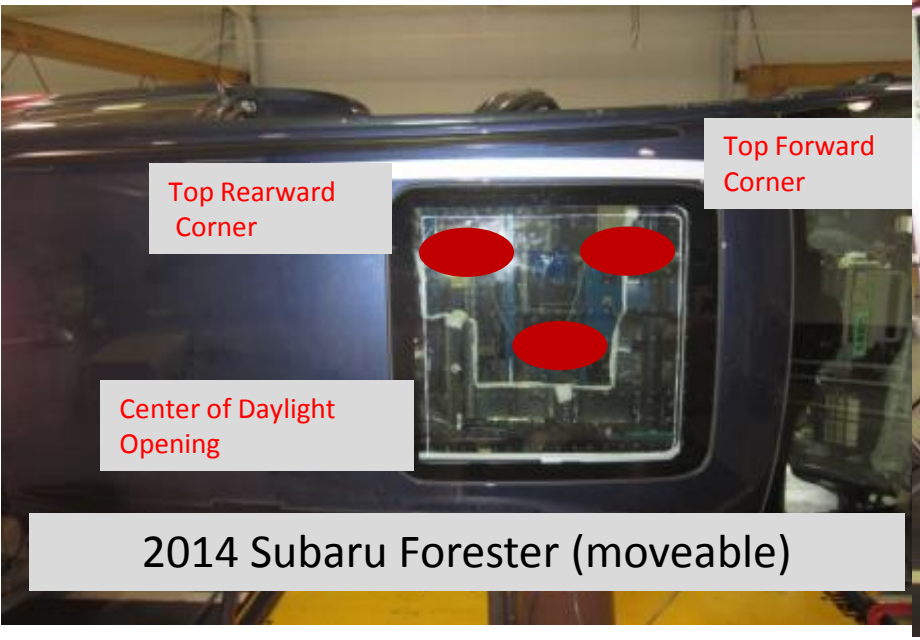
- Featureless Headform
- 40 lbs. (18 kg)
- Displacement from Lin Pot
- Impact Velocity – 10/12.5 mph
- **Used in FMVSS No. 226**

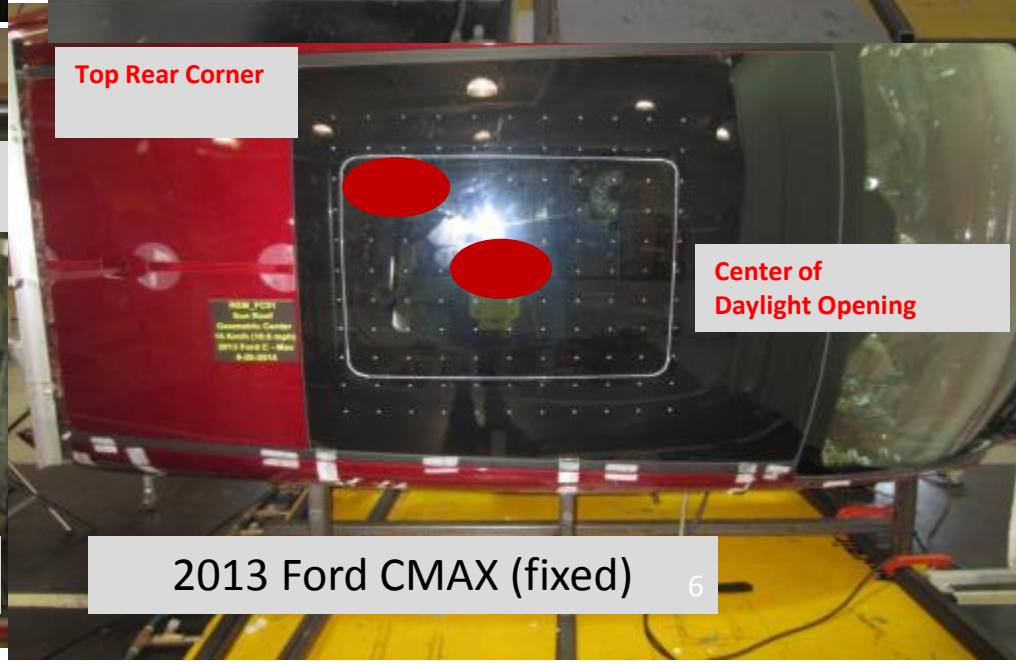
Free Motion Headform (FMH)

- Featureless Headform
- 10 lbs. (4.7 kg)
- Displacement from Accel
- Impact Velocity – 20/25 mph
  - **Equivalent energy to Guided Impactor**


75 mm grid per FMVSS No. 226


Top Rear Corner - Glazing Area of 3rd Row
Center of Daylight Opening - Upper Glazing Area of 2nd Row
Center of Daylight Opening - Glazing Area of 3rd Row
2009 Ford Flex (fixed)


Top Rearward Corner
Top Forward Corner
Center of Daylight Opening
2014 Subaru Forester (moveable)


Top Rear Corner
Center of Daylight Opening
2013 Ford CMAX (fixed)

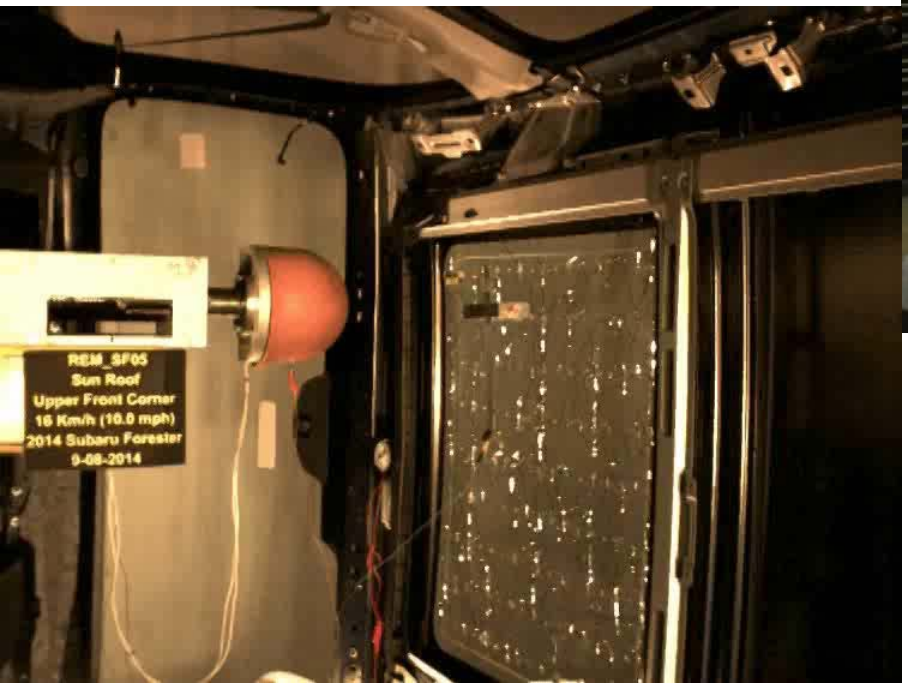
Test Setup

- Stripped vehicle
- Vehicle rotated 90 degrees
- Cut out floor portion to insert the guided impactor
- Reinforced vehicle for stability and to focus on roof.

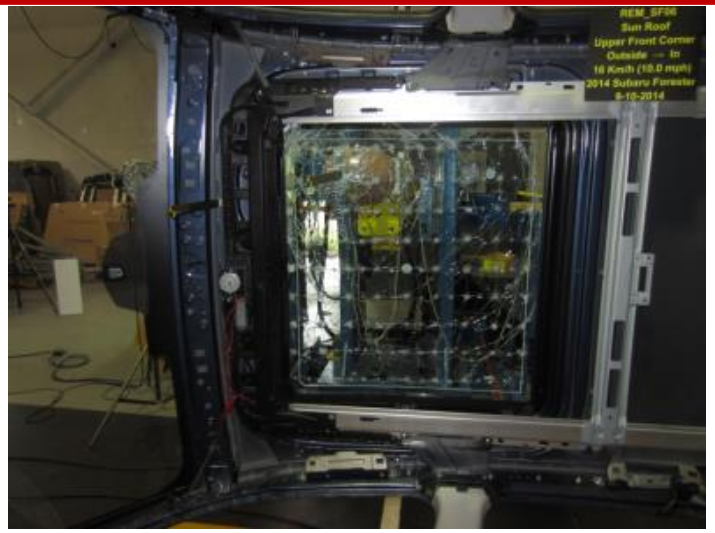
- Daylight opening definition consistent with FMVSS No. 226 procedure
- Impact locations: geometric center and corners.

2014 Subaru Forester (Movable) - Outward

- Test: REM SF05
  - Upper forward corner
  - Impact directed outward
  - 10 mph
  - 222 mm excursion



2014 Subaru Forester (Movable) - Inward



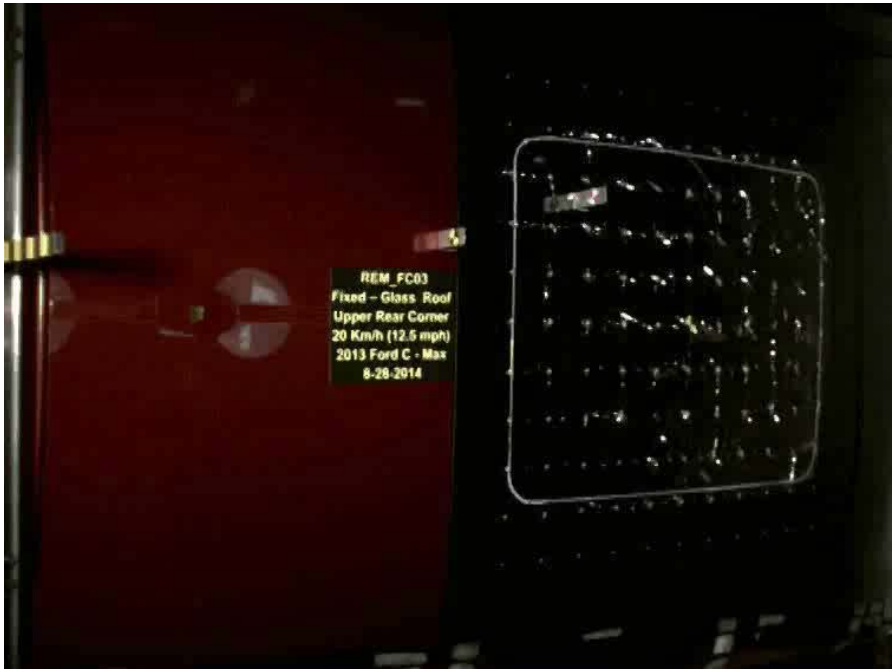
- Test: REM SF06
  - Upper forward corner
  - Impact directed inward
  - 10.1 mph
  - 112 mm excursion

100 mm less than outward impact!

2013 Ford CMAX (Fixed)

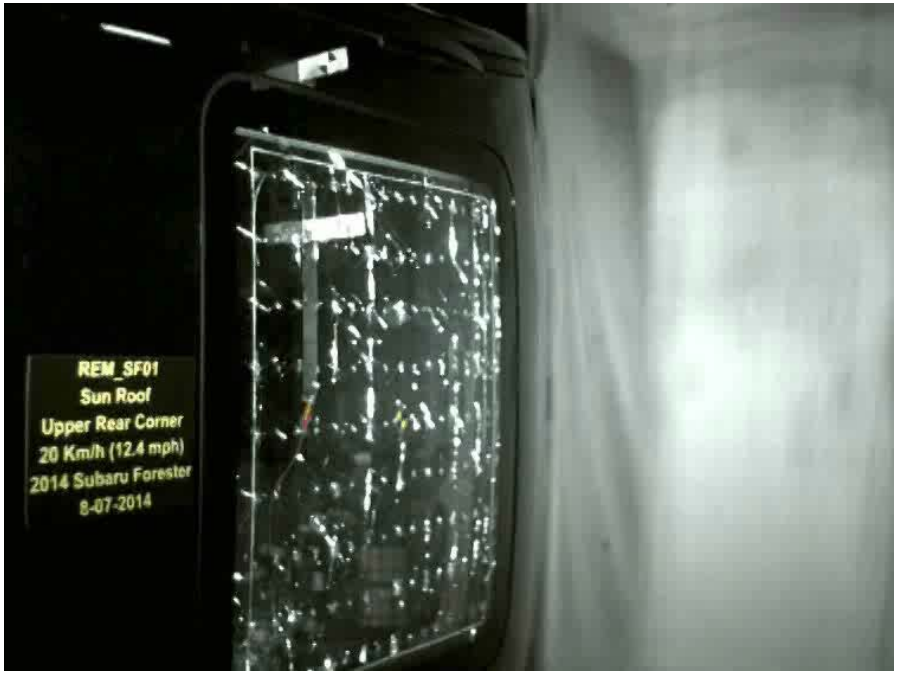
Video:
Geometric Center – 10 mph

Video:
Upper Rear Corner – 12.5 mph



Guided vs FMH Impactor Comparison

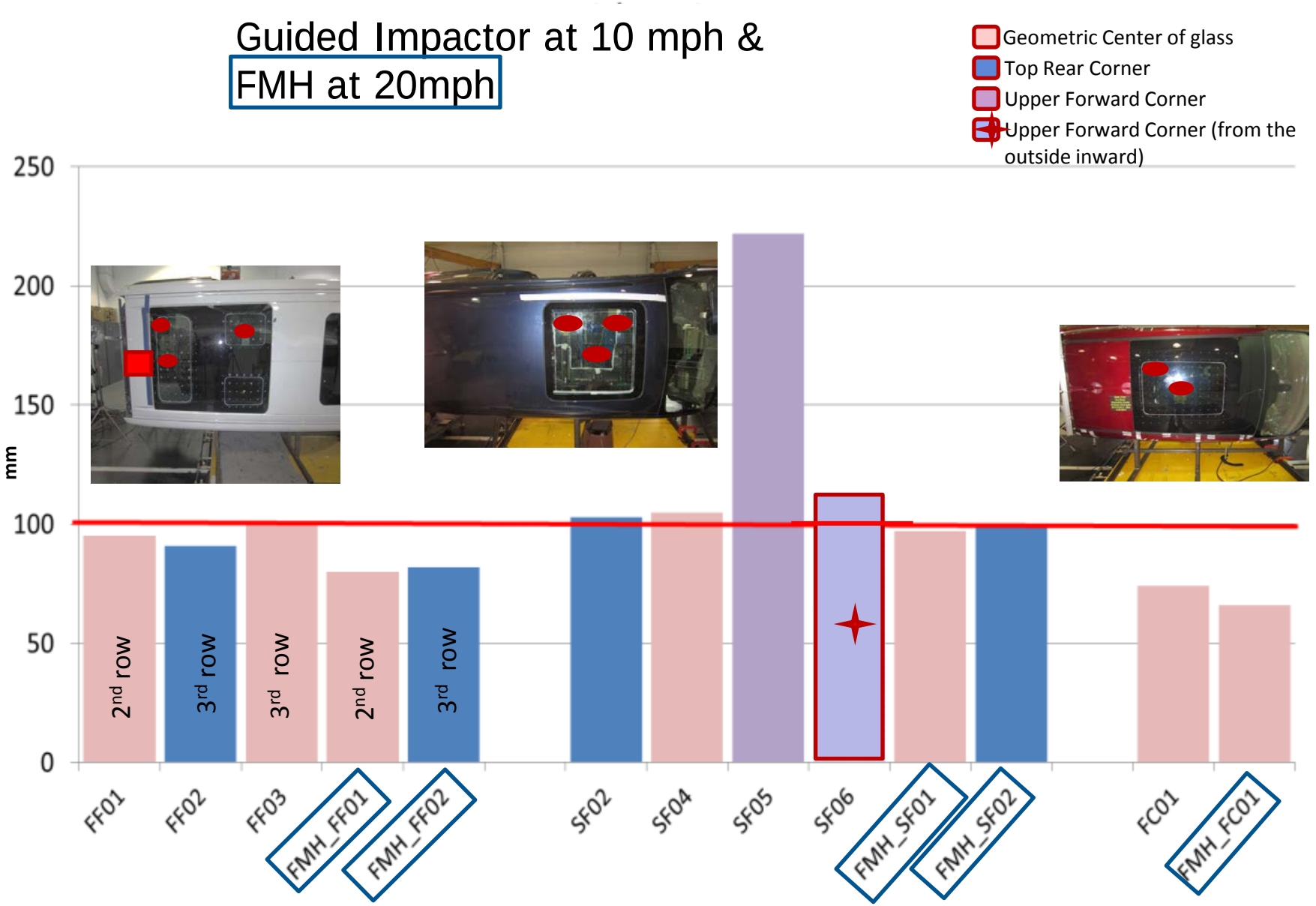
Video: Guided Impactor (12.5 mph)



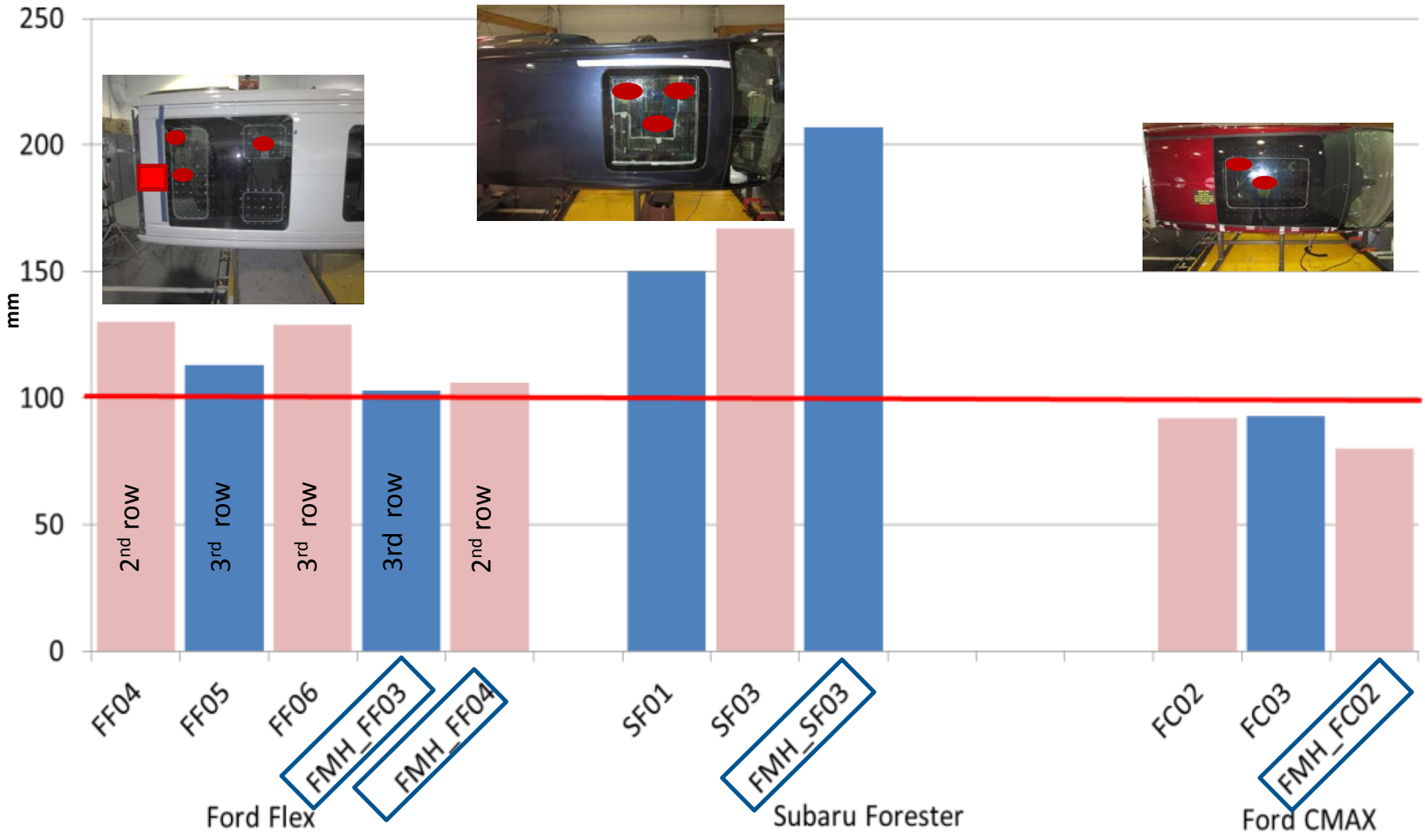
Video: FMH (25 mph)

2014 Subaru Forester (Movable) – Upper Rear Corner

Guided Impactor at 10 mph & FMH at 20mph



Guided Impactor at 12.5 mph & FMH at 25 mph



Testing Observations

- Guided Impactor
  - Impactor was fully contained by glazing
    - Plastic interlayer showed minor tears but not “holed”
  - No glazing/roof bond failure in fixed-glass roof glazings
  - No damage to roof sheet metal
  - Some damage to moveable glazing mechanism
    - Large gap created at leading edge (>100 mm)
- FMH vs. Guided Impactor
  - Guided impactor produced more severe results with equivalent energy
    - Higher excursions, greater damage
- Impacts Directed Inward vs. Outward
  - Impact direction produced different results
  - Inward impacts not representative of real-world

Conclusions

- Testing by rotating the vehicle and using the FMVSS No.226 guided impactor through the floor appears to be feasible
- Additional testing of other roof glazing countermeasures and mechanisms is needed

Continued Research

- Test Procedure Development
  - Test additional vehicles using the FMVSS No. 226 guided impactor (outward direction)
  - Evaluate suitability of FMVSS No. 226 procedures and criterion for roof openings
    - Impact speeds/energy
    - Impact location strategy
    - Excursion limit
- Evaluate Countermeasures
  - Evaluate other laminates
  - Work with OEMs and/or suppliers to obtain non-production laminates for testing
  - Evaluate modifications to existing roof glazing structures
  - Examine effects of sunshades
  - Develop alternatives

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